SOURCE ZONE REMEDIATION USING BIODEGRADATION

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INTRODUCTION

LABORATORY EXPERIMENT 1: METHODS AND RESULTS

Laboratory studies of the effect of bioremediation on source zones were performed by Dr. Joe Hughes lab at Rice University (Carr et al., 2000. First, continuous-flow stirred-tank reactors (CFSTRs) experiments were conducted to evaluate the effect of biodegradation on source zone remediation. Formate was used as the electron donor. A PCE/decane mixture was used to simulate processes involving mixed DNAPLs. The CFSTR experiments were operated for six days to Monitor PCE longevity in presence and absence of dechlorination. “Wash-out” and compositional changes were also studied.

Results from the CFSTR experiments indicated that pseudo-first-order dechlorination rate coefficients for PCE and TCE were determined and were 0.18 and 0.27 h-1, respectively. Total chlorinated ethenes removal from the NAPL was achieved in 13 days in biotic CFSTRs, as compared to 77 days in the abiotic CFSTRs-corresponding to an 83% reduction in longevity of the chlorinated ethenes component of the NAPL.

LABORATORY EXPERIMENT 2: METHODS AND RESULTS

Hughes expanding the laboratory studies by using column studies to evaluate PCE longevity in biotic vs. abiotic systems. A residual DNAPL consisting of a PCE/tridecane mixture was emplaced in three laboratory columns. The columns were inoculated with culture and fed pyruvate at concentrations of 25 mM, 100 mM, and 250 mM. The hydraulic residence time of the column was 3 days. The effluent was monitored for chlorinated ethenes, methane production, and volatile acids. After 80 days, the columns were dissected cryogenically.

Results of the column experiments showed that all columns fermented pyruvate to acetate and propionate with no methane production. PCE was removed 16x faster in a biotic column fed 100mM pyruvate than dissolution alone. Total ethene removal was 5.0X to 6.5X times greater than dissolution alone.

LITERATURE REVIEW

A preliminary literature review of the cost and performance of bioremediation projects was performed. Key results were:

- For a “template site” containing 2725 kg of PCE in a 30 m x 25 m x 29 m source zone, the total cost of electron donor was estimated to be $130,000. This represented 15% of the total cost of a batch-feed delivery system (Harkness, 2000).
- DeStefano and Baral (2000) used commodity-costs for various electron donor and lab results to obtain donor:PCE ratios and estimated that donor costs are $0.04 to $0.85 per pound of PCE.
- Delivery system radius of influence may be a more important cost driver than electron donor type or electron donor unit cost.
- The average cost for 8 electron donor bioremediation systems in the literature on a normalized unit area basis was approximately $1,000,000 per acre. These systems may not all have been located in source zones.

- The reported percentage reduction in dissolved phase concentration for 5 bioremediation systems reported in the literature ranged from an 80.4% reduction to a 99.9% reduction.

A preliminary modeling analysis of source zone bioremediation was performed using the SourceDK software. SourceDK (Farhat et al., 2002) was developed by Groundwater Services, Inc. for the Air Force Center for Environmental Excellence's Tech Transfer Division. This modeling analysis used the "Template Site" described above, together with an assumed source exit concentration of 10 mg/L and a Darcy groundwater velocity of 12.5 ft/yr (~50 ft/yr seepage velocity), The analysis indicated that:

- CASE 1: NO BIODEGRADATION. For a no-biodegradation case, the time required to achieve a 99% reduction in source concentration (from 10 mg/L to 0.10 mg/L) was estimated to be > 500years.
- CASE 2: LOW BIODEGRADATION. For the case with a relatively low rate of dissolved-phase biodegradation (lambda equal to 1 per year, or a rate similar to what is seen at solvent natural attenuation sites), the time required to achieve a 99% reduction in source concentration was reduced to 176 years.
- CASE 3: MODERATE BIODEGRADATION. For a moderate rate of biodegradation (lambda equal to 10 per year), he time required to achieve a 99% reduction in source concentration was reduced to 24 years.
- CASE 4: HIGH BIODEGRADATION. For a high rate of biodegradation (lambda equal to 100 per year, or a rate shown to be present in controlled lab and field-scale experiments with electron donor addition), he time required to achieve a 99% reduction in source concentration was reduced to 3 years.

CONCLUSIONS

- Cost data suggests the relative cost of electron donor cost can be relatively small compared to total project cost.
- The cost of the delivery system is likely to be a more important factor than the electron donor cost.
- Data from laboratory studies and a SourceDK modeling analysis indicates that bioremediation can be effective on a technical basis le for treating source zones.
- The decision to use bioremediation as a source zone management technique vs. other methods (i.e., passive barriers, containment, chemical oxidation, thermal treatment) will likely be controlled by the life-cycle cost of different management options and site-specific risk and regulatory factors.

REFERENCES

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